AUTOMATIC DOSE ADAPTATION AS A FUNCTION OF PATIENT BODY MASS INDEX IN CT CALCIUM SCORING

DESCRIPTION

The present invention relates to the diagnostic imaging arts. It finds particular application in conjunction with calcium scoring with CT scanners and will be described with particular reference thereto.

The presence of calcium deposits in the coronary arteries has been recognized as a marker for atherosclerotic coronary artery disease. Patients who are at risk are screened for calcium in order to follow the calcium build up rate and to assess the influence of certain medication on this rate. Each screening generates a diagnostic image in which tissue above a preselected threshold, e.g., 130 HU, is assumed to be calcium and is marked with a differentiating color to develop a calcium score. The images are compared with images from previous examinations to determine the change in the calcium deposits with time.

Repeated calcium scoring examinations can deliver a substantial cumulative amount of ionizing radiation. Exposure to radiation is a concern, especially in subjects in the screening population. Although the CT radiation dose may be relatively low per subject per scan, the added risk to the population is substantive, with unknown long-term effects. Accordingly, attempts have been made to reduce the radiation dose.

Calcium scanning has been conducted with an arbitrarily selected fixed low dose, such as driving the x-ray tube with 40 mAs or other fixed small tube currents. While the calcium scoring examinations have, for some patients, been excellent at low doses, the examinations for other patients have had unacceptably high noise. High noise causes numerous voxels of the reconstructed image to have a noise influenced Hounsfield unit (HU) level. Because noise is additive (subtractive) to the Hounsfield value of each pixel, noise can cause voxels below the threshold to be raised above the threshold and appear as calcium. In other instances, random noise appearing in a voxel corresponding to calcium can drive the HU value of the voxel below the calcium threshold. By consensus, it has been decided that 20 HU of noise is the required noise for acceptable calcium scoring examinations.

It has been found that in low dose (low mAs) diagnostic images, good noise statistics are achieved for subjects with a relatively small lateral thickness and high

noise statistics occur for patients with a larger lateral thickness. It has been proposed that patients be divided into three size categories: small (less than 32 cm lateral thickness), medium (32-38 cm lateral thickness), and large (over 38 cm lateral thickness). The proposal calls for manufacturers of CT scanners to set a recommended dose (mAs) for
5   patients in each size range. Although this solution has advantages, it still irradiates patients below the upper thickness end of the two thinner ranges with more radiation than necessary. Moreover, it may not radiate patients significantly over 38 cm in lateral thickness with a high enough dose to achieve the 20 HU maximum noise level standard.

The present invention provides a new and improved solution which
10   overcomes the above-referenced problems and others.

In accordance with one aspect of the present invention, a diagnostic imaging device is provided. An x-ray tube irradiates a patient with an x-ray beam. A dose
15   controller controls milliamperes of an x-ray tube current to control radiation dose. A dose processor calculates a target maximum patient dose in accordance with physical parameters of the patient to be examined.

In accordance with another aspect of the present invention, a method of diagnostic imaging is provided. A radiation dose of an x-ray tube is selected in accordance
20   with physical parameters of a patient to be examined. An x-ray diagnostic examination of the patient is performed with an x-ray beam with the selected radiation dose.

In accordance with a more limited aspect of the present invention, the maximum target radiation dose is achieved with an x-ray tube current (mAs) that is proportional to the patient's body mass index (BMI) squared.

25   One advantage of the present invention is that it minimizes radiation dose, while still maintaining noise levels below a preselected threshold.

Another advantage of this invention resides in its simplicity and ease of implementation.

Another advantage resides in maintaining a consistent noise level over a
30   series of images acquired over a long period (years).

Still further advantages of the present invention will be appreciated to those of ordinary skill in the art upon reading and understand the following detailed description.

The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating the preferred embodiments and are not to be construed as limiting 5   the invention.

FIGURE 1 is a diagrammatic illustration of a diagnostic imaging system in accordance with the present invention; and,

FIGURE 2 is a graphical illustration of the relationship between the mAs and the body mass index at the selected noise level of 20 HU.

10

A CT scanner **10** includes an x-ray tube **12** which generates a beam of radiation, such as a fan-beam or cone-beam. The radiation is received by a detector array **14** disposed across an examination region **16** from the x-ray source to receive radiation that has passed through a portion of a subject in the examination region. An x-ray controller **18** 15   controls the milliamperes (mAs) values of the x-ray tube which, in turn, adjusts the dose of radiation delivered to the subject in the examination region **16**.

A user input device **20** includes a means **22** for inputting the patient's weight, a means **24** for inputting the patient's height, and a means **26** for inputting other 20   selected scan control parameters and information, as are conventional in the art. These inputting means typically include a keyboard, number pad, touch screen, or the like. A target required noise memory **28** stores the target required noise level. In the preferred embodiment, the target required noise level is a preselected standard which remains fixed, but which may be changed if the standard changes. Alternately, the required noise can be 25   designated through the user input means to enable the clinician to select a different target noise level.

A dose selection processor **30** includes an algorithm or means **32** for squaring the patient's height and an algorithm or means **34** for dividing the patient's weight by the square of the patient's height to generate the body mass index (BMI) which 30   is defined as being the patient's weight divided by the square of his height. The body mass index is stored in a buffer **36**. An algorithm or means **38** squares the body mass index. The target required noise from the required noise memory **28** accesses a look-up table **40**

to retrieve a corresponding constant. In the preferred embodiment in which the weight is entered in kilograms, the height in meters, and the target required noise is 20 HU, an appropriate constant is 0.05. A multiplying algorithm or means 42 multiplies the square of the body mass index by the constant which generates the mAs value, which may be stored

5   in a corresponding buffer 44. The calculated mAs value is communicated to the dose controller 18 which controls the x-ray tube to generate a tube current with the calculated level of milliamperes (mAs).

FIGURE 2 is a graphical illustration of the relationship between the mAs and the body mass index squared at the selected noise level of 20 HU. It will be noted that

10   this relationship is a linear relationship with a slope equal to the constant for the selected noise level. For a target maximum noise of 20 HU, the slope of the linear relationship is 0.05. For lower noise, the slope is steeper, and for higher noise, the slope is more shallow.

Once the dose level has been set, the user input device 10 enables a scan controller 50 to initiate a CT scan. As the radiation source 12 is rotated around the

15   examination region, a reconstruction processor 52 reconstructs the image data from the detector 44 into a diagnostic image representation. A thresholding means or algorithm 54 thresholds the resultant diagnostic image to differentiate calcium from other tissue, e.g., at 130 HU. The thresholded, calcium-enhanced image representation is stored in an image memory 56. A video processor 58 withdraws selected portions of the calcium-enhanced

20   image representation for display on a monitor 60. Preferably, one or more prior calcium scans of the same subject are retrieved from an archive 62. A comparing algorithm or means 64 compares the most recent calcium scan image representation from the memory 56 with the archived image representations. The video processor may then convey a difference image between the most recent calcium scan image representation and a selected

25   prior calcium scan representation to the monitor to generate a display indicative of the change in calcium between the two scans. Optionally, a ciné image processor 66 displays the historical and new image sequentially in a ciné mode. A calcium score calculator 68 calculates the calcium score from the current image. A graphing means or processor 70 compares a plurality of calcium scores, including the current calcium score and others from

30   the archive to generate a graphical display indicative of calcium build-up.

The invention has been described with reference to the preferred embodiments. Modifications and alterations may occur to others upon reading and

understanding the preceding detailed description. It is intended that the invention be constructed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.